A Navigating System for Ventilation Network Spatio-Temporal Control

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ABSTRACT

This paper presents a navigation system for spatio-temporal control of mine ventilation network to help keep miners safe in mine emergency situations such as mine fire, spontaneous combustion, and gas emission. The system is composed of sensors, computer simulation and binary controllers. The ventilation sensors are placed in specific branches of the ventilation network to monitor ventilation parameters such as air velocity. The Horonai coal mine, Hokkaido, Japan is used as an example to illustrate the applicability of the navigation system as on and in providing a safe evacuation route and to estimate the time interval to achieve steady airflow on and in determining distribution in the network.

KEYWORDS

Monitoring Airflow Rate, Macroscopic Characteristics, Ventilation Network, Ventilation Transition Diagram, Evacuation Route, Non-steady Flow.

INTRODUCTION

It is vitally important to take appropriate measures, without delay, to keep miners safe in mine emergency situations. These measures, wherever possible, should be based on up-to-date monitoring and control technology. The evac-uation route should be carefully planned and evaluated by measuring airflow rate in the key branch. Consideration must be given to time-dependent state of the airflow to avoid any secondary accident due to an unpredicted state of the underground environment. Wang, *et al.*, (1985) reported factors that may allow to keep the ventilation cost at an acceptable level by reducing the aerodynamic resistance in a branch under normal state of airflow in the network. Natural ventilation occurs primarily due to the air temperature in the network. Therefore, any regulator located in a network should be determined so that it will not increase the cost of a main fan (Tominaga, *et al.*, 1984).

Emergency situations from mine fires and gas outbursts are common in underground coal mines. In an earlier paper (Tominaga *et al.*,1992) reported on a ventilation monitoring and control system which has the capability to analyze the control of airflow in a network by measuring, transmitting and analyzing equipment. The ventilation diagram showing the macroscopic characteristics in relation to the airflow rate in sensored branches is used to estimate the aerodynamic state of a specified branch. This paper will present a method to estimate the convergence time to reach steady state airflow rate following the opening/closing of a specified regulator by using ventilation transition diagram. If an evacuation route is in the return airway, the airflow in the branch should be changed to fresh air. This paper shows the elapsed time needed to achieve steady state of air distribution from its initial state in Horonai coal mine.

VENTILATION ANALYSIS

The Hardy-Cross method, Delta-Star transform method, Delta-V transform method and others are routinely used for ventilation network analysis. Delta-V transform method (Wang and Tominaga, 1996) can calculate theoretical airflow rates in Delta circuit under the given airflow rates of input/output of the delta circuit. A complicated ventilation network, however, contains several delta circuits. In such cases, Hardy-Cross method is generally used to estimate the airflow rate for a navigation system. The software developed by Tominaga, *et al.*,(1991) includes a ventilation analysis segment, and network graphics. The program is capable of drawing a diagram for monitoring aerodynamic resistance of a branch and ventilation transition diagram. The computer program can be used for steady state analysis of the airflow rate in a network. Tominaga, *et al.*, (1988) presented a simulation method for non-steady state ventilation analysis that relates to gas outburst, mine fire and mine air conditioning.

SOFTWARE

These computer programs were developed using N88BASIC, and MS-DOS V3.3. A personal computer with a 150MHz Pentium processor takes approximately five seconds to estimate the airflow rate in the Horonai coal mine network, composed of 191 branches, 3 inlets and one main fan.

APPLICATION

A ventilation network of the Horonai coal mine is used to illustrate the proposed navigation system. Figure1 shows the network comprising of all 191 branches, and the regulators on all 33 branches are shown in filled circles. Open circles on the network are locations of air velocity sensors.

Figure 2 shows a diagram for aerody-namic resistance in Branches.

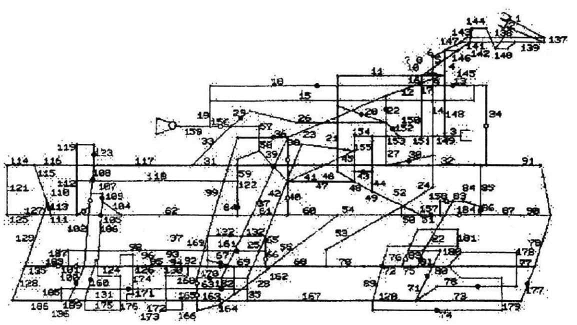

Figure 1. A ventilation network of the Horonai coal mine.

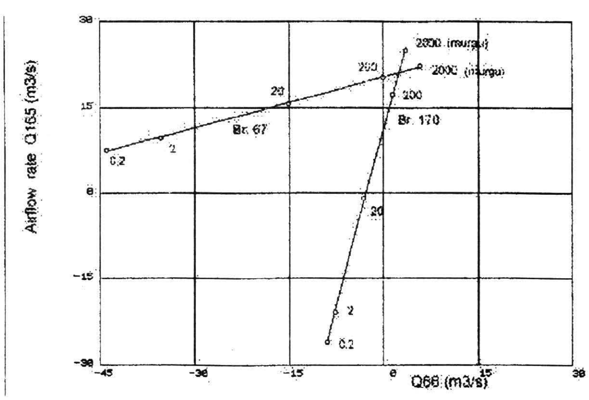

Figure 2. Diagram showing aerodynamic resistance of branches 67 and 170 by sensor branches 66 and 165

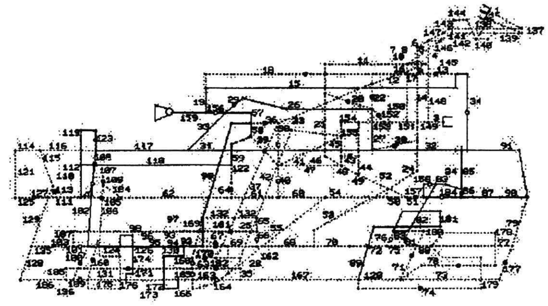

Figure 3. Return airways from three working faces 89,172 and 174 under initial state.

66 and 165. The solid lines in a network in Figure 3 show return airways from three working faces. These are shown as Branch 89, 174 and 176. Two regulators placed on branches 67 and 170 respectively are capable of changing their opening size; they could be any one of the six possible openings (1: present state, 2: full, 3: three quarter, 4: half, 5: a quarter, 6: close).

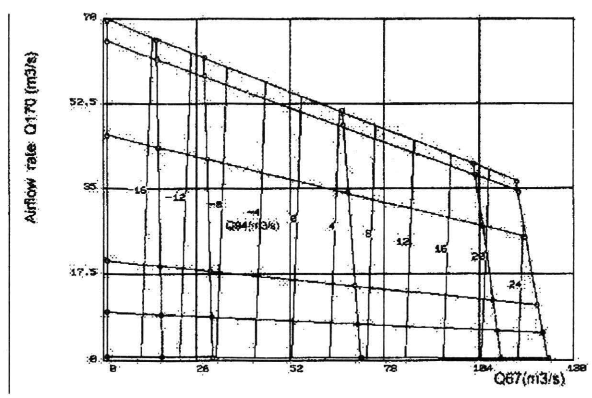

Figure 4. Ventilation transition diagram for a branch 94 by adjusting regulators in Branches 67 and 170.

Figure 4 shows the ventilation transition diagram to estimate airflow variations in Branch 94 by changing the opening state of a regulator located on Branches 67 and 170, respectively.

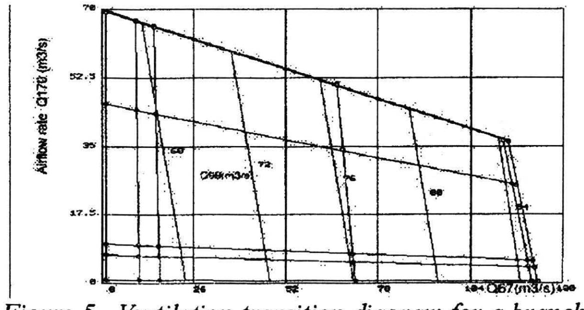

Figure 5. Ventilation transition diagram for a branch 99 by adjusting regulators in branches 67 and 170.

Another example of the ventilation transition of Branch 99 which results from the change of aerodynamic resis

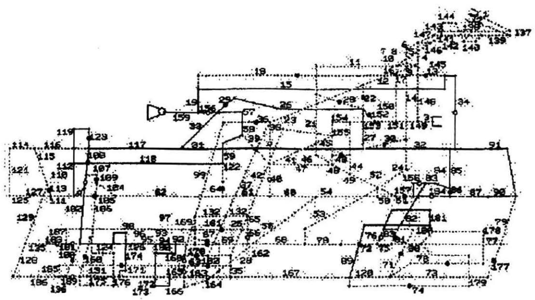

Figure 6. Return airway from three working faces 89, 172 and 174 under decreased aerodynamic resistance of a regulator in the branch 67.

tances in regulator 67 and 170 is shown in Figure 5.

The solid lines in Figure 6 show the return airways after the change of aerodynamic resistance of a Branch 67 from 400 murgu to 1 murgu.

The monitoring diagram shown in Figure 2 can be used for checking the opening state of the regulator. It is important to confirm that the point given by airflow rate of sensor branches 66 and 165 is on lines in the Figure 2. If evacuation route includes both Branches 94 and 99, it is available to change the opening state of the regulator located on Branch 67 as shown on both diagrams (Figures 4 and 5).

Simulation was conducted using three cases of aerodynamic resistance of Branch 67 with re-sistance values of 1 murgu, 10 murgu and 100 murgu. Calculated airflow on both Branches 94 and 99 are intake air when the aerodynamic resistances of 1 murgu and 10 murgu are used in Branch 67.

It is shown by comparing ventilation diagrams in Fig.4 and 5 that the decrease in aerodynamic resistance in branch 67 causes the change in airflow direction in branch 94 and the increase in air quantity in branch 99.

Non-steady state of airflow of the main fan is determined by the following procedure. The total length of the airways in the network is 46km and a mean value of the cross sectional area of an airway is 11m2. Operating point (294.8 m3/s, 460.3 mmAq) on the characteristic curve of a main fan is estimated under initial state of the mine resistance of 5.296 murgu with an aerodynamic resistance of 400 murgu of Regulator 67.

Non-steady flow of air was also simulated by using Newton's dynamic equation (Tominaga, 1988) for two cases of resultant resistance 4.67 murgu and 4.88 murgu, while the aerodynamic resistances of the Regulator 67 are 1 murgu and 10 murgu respectively. It can be seen in Figure 7 that increases in the aerodynamic resistance, more elapsed time is needed to reach the steady state of airflow rate.

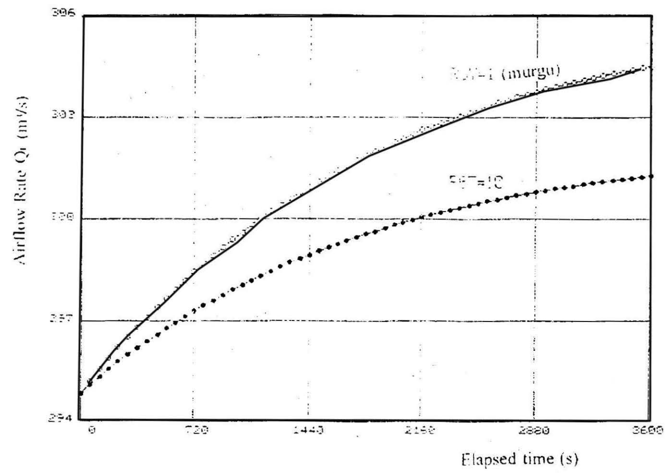

Figure 7. Non-steady state of airflow on the main fan by adjusting aerodynamic resistance of the regulator in the Branch 67.

CONCLUSIONS

This paper introduced a navigation system which consists of many sub-programs to conduct ventilation analysis, monitoring of branch aerodynamic resistance in a network, generating ventilation diagram in a specified branch, and network air distribution diagram, as well as plotting unsteady state of airflow rate at the main fan. It also illustrates the procedure for changing return air to fresh air path.

The computer program allows rapid conver-gence time for calculating airflow following changes in the aerodynamic resistance of a branch taking into account any changes in the opening of the regulator.

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